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The purpose of this study was to examine both objective and athlete perceived biomechanical outcomes of Block Zero training thought to be associated with ACL injury risk potential. There were two specific aims of this study.

The purpose of Aim 1 of this study was to examine the extent to which Block Zero training increased knee:ankle ratio during the performance of the Drop Jump Screen Test. Thirteen female high school athletes from girls' volleyball, basketball, softball, and soccer comprised the sample. A paired t-test indicated participants demonstrated increases in knee:ankle ratio and increases in strength from pre to post test. Spearman's correlation indicates there is a strong positive relationship between increased strength gains and increased knee:ankle ratio.

To further address Aim 1, the perceived benefits of Block Zero on past participants were examined. Twenty-four survey responses comprised the sample. Results from McNemar's Test for correlated proportions indicated participants report positive perception of Block Zero training.

The purpose of Aim 2 was to compare injury data from the host high school to three area high schools to determine if athletes who participated in Block Zero were less susceptible to ACL injury than those who did not participate in Block Zero. While results were not statistically significant, with the exception of girls' volleyball, the host school experienced lower injury ratios. These positive results suggest that Block Zero

training should be studied in the future as one potential way to provide protection against ACL injury.

THE EFFECT OF AN INTRODUCTORY STRENGTH TRAINING PROGRAM ON ACL INJURY RISK FACTORS

by

Eric Neil Cash

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the Faculty of The Graduate School at
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of the Requirements for the Degree
Doctor of Education

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Approved by

____
Committee Chair

This study is dedicated to all of my former and current athletes that inspire me everyday. To all of my former and current staff, I am grateful and appreciative for your patience, understanding, and knowledge that you have shared.

APPROVAL PAGE

This dissertation written by Eric Neil Cash has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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Date of Acceptance by Committee

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Date of Final Oral Examination

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To Coach Batson, thank you for giving me an opportunity to enter the field of strength and conditioning fourteen years ago. My experiences as a graduate assistant helped to create a firm foundation to develop my coaching philosophy. Your guidance and mentorship over the last fifteen years mean more than you will ever know. Coach Sisk, I want to thank you for your friendship, knowledge and guidance that has helped mold my coaching career. You continue to be a voice of reason in a chaotic profession. Coach Kenn, thank you for allowing me to be part of your network. The Tier System and Block Zero serve as cornerstones of my coaching philosophy. Thank you for your knowledge and insight behind Block Zero.

To my parents, Max and Susan, your example as parents and drive for the importance of education set a path for me to follow. I am eternally grateful for your love, patience, and guidance.

To my children, you are an inspiration to me each and every day. My loving daughter McKinley, thank you for your patience and understanding through this process. It is my hope that you understand the importance of perseverance and the importance of the continuous quest for knowledge. My son Emory, I am so grateful for your wild and happy spirit! I lucky to call you are my son.

Finally, Sheri, your ability to endure, hold steadfast, and persevere motivates me to be a better husband and father. I am so blessed we get to do this crazy life together!

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CHAPTER I

PROJECT OVERVIEW

Background

As early as 1983, research indicated a rising trend in anterior cruciate ligament (ACL) injuries where eighty percent of injuries are caused by non-contact mechanisms (Noyes, Mooar, and Matthews, 1983). A sixteen-year epidemiological study (1988-2004) presented by the National Collegiate Athletic Association (NCAA) showed that female gymnasts suffered an incidence of ACL injuries in .33 per 1000 athlete exposures and that three of the four sports with the highest incidence of ACL injuries were female sports: gymnastics, basketball, and soccer. A more recent eight-year epidemiological study from 2004-2005 to 2012-2013 indicates that when compared to male soccer players, females have .10 rate of injury (per 1,000 exposures) compared to males which is a .03 rate of injury (Agel, Rockwood, and Klossner, 2016). Similar results were found for basketball where females have .22 rate of injury compared to .08 for males, and for lacrosse where females have a .23 rate of injury compared to .13 for males (Agel et al. 2016).

The high incidence of ACL injury and the increased rate of injury for females has led researchers to develop ACL injury prevention programs that focus on neuromuscular and biomechanical risk factors, as they are considered modifiable risk factors (Voskarian, 2013). A key risk factor associated with non-contact ACL injuries in females that these programs have targeted is knee valgus. Hewett, Myer, Ford, and Heidt (2005) conducted an injury surveillance study and found that subjects that suffered non-contact ACL injuries demonstrated significant increases in lower extremity valgus and knee abduction. In a video analysis of 39 basketball ACL injuries, Krosshaug, Nakame, Boden, Engebretsen, Smith, Slauterbeck, Hewett, and Bahr (2007) found female basketball players demonstrated a 5.3 times higher relative risk of sustaining a valgus collapse at the time of injury when compared to male basketball players. Injury prevention programs that have focused on neuromuscular and biomechanical risk factors have documented success in reducing the rate of non-contact ACL injury (Hewett, Lindenfeld, Riccobene and Noyes, 1999; Mandelbaum, Silvers, Watanabe, Knarr, Thomas, Griffin, Kirkendall, and Garrett, 2005; Myer, Ford, Palumbo and Hewett, 2005).

Despite the efforts of current ACL injury prevention programs to address neuromuscular and biomechanical risk factors, a gender difference in ACL injury rates still exists for females when compared to males. Stanley, Kerr, Dompier, and Padua (2016) indicate females remain two times as likely to sustain an ACL injury when compared to males that compete in the same sport. Noyes and Westin (2012) suggest a variety of ACL injury prevention programs have been developed to address ACL injuries, however, the components of intervention programs vary tremendously. Noyes and Westin (2012) found programs typically include plyometrics and agility exercises; however, only three programs implemented strength training: *Sportsmetrics*, *PEP*, and the *FIFA 11* (Noyes and Westin, 2012). Intensity and duration of programs range from 15 to 120 minutes and programs have been implemented during the season and prior to the start of the athletic season starting (Noyes and Westin, 2012). Yoo, Lim, Ha, Lee, Oh, Lee, and Kim (2010) conducted a meta-analysis on the effect of neuromuscular training on the prevention of ACL injuries in female athletes and found that while a certain combination of neuromuscular and biomechanical components could not be verified, plyometric and strength training are necessary factors for a prevention program.

However, a recent systematic review indicated that injury prevention programs often do not employ common strength training guidelines such as progressive overload (Taylor et al., 2015). Furthermore, Davies, Reimann, and Manske (2015) indicated the most significant contraindication to plyometric training is exposing the athlete to plyometrics before a foundational strength base is developed. For example, analysis of the *Sportsmetrics* program reveals that athletes begin jump training in week one prior to the implementation of strength training exercises (Table 1, Appendix A, Noyes, Barber-Westin, Tutalo, Stephanie, and Campbell, 2013; Noyes, Barber-Westin, Smith, Campbell, and Garrison, 2012). Jump training exercises in the *Sportsmetrics* program are progressed with time (adding seconds) rather than adding reps and tracking foot contacts as suggested by the National Strength and Conditioning Association (NSCA) (Baechle and Earle, 2008). The *Prevent injury and Enhance Performance (PEP)* program only incorporates three strength training exercises (walking lunges, Russian hamstrings, and calf raises) all of which are implemented for one minute (Table 2, Appendix B, Santa Monica, 2017). There is no evidence of progressive overload in the PEP program. The *FIFA 11* program also includes strengthening exercises: plank, side plank, Nordic hamstrings, and squats (Table 3, Appendix C, FIFA, 2007). While there is evidence of progressing in difficulty of exercise, there does not appear to be a clear progression in repetitions or time.

The development of relative strength (defined as strength in relation to body weight or body size) is also important in ACL injury prevention and is largely neglected by the aforementioned prevention programs. The *FIFA 11+* and *PEP* both include Nordic/Russian Hamstrings, which represents relative strength training and have a proven effect on hamstring stiffness, which results in improved landing biomechanics (Blackburn and Norcross, 2014). The *FIFA 11+* also employs relative strength holds with the use of planks and side planks which supports Earl and Hoch (2011) which found that strengthening and improving core musculature improved core strength, as well as reducing the knee abduction moment. However, due to the multifactorial nature of non-contact ACL injuries, relative strength needs to be applied to target other areas. Brent, Myer, Ford, and Hewett (2006) present the need for relative strength in that adolescent females do not gain relative abduction strength as compared to adolescent males. Brent et al. (2006) conclude the increased risk of ACL injury for females may be due to the absence of increased relative hip abduction strength as they age through adolescence.

Current ACL injury prevention programming that have included strengthening and plyometrics are reported to be effective in reducing ACL injury rates (Voskanian, 2013); despite the fact the programs do not employ suggested strength training guidelines or the development of relative strength. If strength training is a critical element of these programs, developing programs that adhere to progressive overload and the development of foundational strength prior to plyometric training, as well the development of relative strength should yield more effective injury reduction.

Rationale

A sex-disparity still exists in ACL injury rates with females more than two times as likely to sustain an ACL injury (Stanley et al., 2016). The continuing rise in ACL injuries, particularly in females, has led to the development of prevention protocols to combat and reduce ACL injuries by targeting modifiable risk factors (Hewett et al., 1999; Gilchrest, 2008; Irmischer, 2004; Soligard, 2008, Myer et al, 2006; Myer, Ford, Brent, & Hewett, 2012). While ACL injury prevention programs have proven to be effective in the short term, the rate of ACL injury, and the sex difference in ACL injury occurrence, remains high dictating the need for continued improvement in the effectiveness of these prevention programs (Benjaminse, Welling, Otten, and Gokeler, 2015). Altered knee joint biomechanics, especially those that lead to valgus collapse during landing, cutting, and deceleration, are considered major risk factors for non-contact ACL injury (Fort-Vanmeerhaeghe, Romero-Rodriguez, Montalvo, Kiefer, Lloyd, and Myer, 2005).

To that end, Brent et al. (2005) indicated that, compared to adolescent males, females do not gain relative hip abduction strength as they age, which may result in dynamic knee valgus predisposing females to increased risk of ACL injury relative to males. This is important, as a recent systematic review indicates that current prevention programs lack common strength training guidelines that call for progressive overload (Taylor, Waxman, Richter, and Shultz, 2015). This preliminary study is expected to have a positive impact on the gender gap in ACL injury rates. Specifically, this proposal will utilize an introductory strength training protocol, Block Zero, as a means to reduce ACL injury in female athletes who do not have prior experience in a strength and conditioning setting.

Despite this knowledge, current prevention programs often do not follow recommended strength training guidelines that are known to have positive impact on muscular strength (specifically progressive overload). Specifically, plyometrics are often introduced without first developing a solid strength foundation. This is a problem because introducing plyometrics prior to development of foundational strength may result in a lack of coordination and motor control when performing these tasks, and ultimately inhibits the progression to more advanced exercises. Thus, there remains a critical need to investigate the utilization of recommended strength training guidelines and the development of an initial strength foundation in ACL injury prevention programs if sport and exercise professionals are to be most effective in closing the sex disparity gap in ACL injury.

Purpose Statement

The purpose of this program evaluation is to examine both objective and athlete perceived biomechanical outcomes of Block Zero training thought to be associated with ACL injury risk potential. The central hypothesis, which is based on prior strength training literature and observational experiences with Block Zero, was that athletes who increase strength in response to their Block Zero training will increase knee separation distance (a 2-dimensional measure of bi-lateral knee valgus collapse between) during the high impact landing of the Drop Jump Screen Test, and that athletes who have participated in block zero in the past will report that Block Zero has had a positive impact on jumping mechanics, and will report fewer ACL injuries than athletes that did not participate in Block Zero. The rationale for this study was that demonstrating the implementation of proper strength training protocols which may positively impact knee valgus, future ACL prevention programs will be more effective at reducing the sex-disparity in ACL injuries. Block Zero is a widely implemented program in collegiate and high school strength settings, however, Block Zero has yet to be studied. The ***specific aims*** are:

Specific Aim 1: Identify the extent to which Block Zero Training increased the knee:ankle ratio during performance of the Drop Jump Screen Test landing. The working hypothesis was that Block Zero training would increase the knee:ankle ratio during the performance of the Drop Jump Screen test landing from pre- to post- test.

Addition to Aim 1: **Determine perceived benefits of Block Zero training on past participants of Block Zero.** It was hypothesized that past participants of Block Zero would have a positive perception of Block Zero concerning knee symptoms and certain maneuvers during sport participation.

Specific Aim 2: **To determine if athletes who participated in Block Zero were less susceptible to ACL injury than those who did not participate in Block Zero.** The working hypothesis was that athletes that do not participate in Block Zero would incur more ACL injuries than athletes who participated in Block Zero.

Methods

Specific Aim 1

The sample for the study were 9th grade female athletes from multiple sports. All freshmen athletes were exposed to Block Zero training. All athletes in this preliminary study received Block Zero training. It seemed unwise, and possibly unethical, to use a control group in which athlete would not receive Block Zero training before more is known about this type of training. Prior to beginning the program, participants were given parent permission forms and consent forms approved by the Institutional Review Board (IRB). Only those with parent permission and consent forms were included in the results of the study. Block Zero serves as a foundational strength training program, therefore, these particiapants were chosen due to their novice experience in strength and conditioning. The sports represented among the participants were girls volleyball, girls softball, girls basketball and girls soccer. There were a total of 13 participants that were included in the reporting of results.

Block Zero Training. The Block Zero program utilized in this study was derived from Coach Joe Kenn (2016). The eight week program follows periodization guidelines defined by the NSCA. Periodization cycles are defined as macro (typically a year), meso (several weeks to several months), and micro (one to four weeks) (Baechle and Earle, 2008). The Block Zero program represents an eight week mesocycle that is divided into two four week microcycles (Table 4, Table 5, Appendix D). The athletes participated for 45 minute sessions three days per week. The daily program was divided into four areas:

athletic position, jumping mechanics, stabilization, and relative strength. The eight-week program was divided into two four week phases.

Phase two progressed in intensity reflecting the principle of progressive overload. Exercises increased in repetitions or by adding time. The athletic position aspect area of the program placed an emphasis on the power position and landing position. During the jumping mechanics portion of the program, athletes were introduced to low intensity plyometrics. Prescription of repetitions for plyometrics were well below the recommendations set forth by the NSCA for novice athletes (3 sets of 6 for a total of 18 foot contacts) (Baechle and Earle, 2008). Stabilization refers to isometric strength. Participants of Block Zero performed upper and lower body exercises and held the isometric contraction for a prescribed time.

The final area, relative strength, placed the athlete through upper and lower body exercises without an external load. Intensity was manipulated through reps, time, and tempo. Athletes performed five isometric exercises for time during pre and post training to measure increases in isometric strength: chin up hold, isometric push up, isometric single leg glute bridge, isometric split squat, and isometric squat.

Drop Jump Screen Test. Before an athlete could complete the Drop Jump Screen Test, she had to first understand how to perform the Drop Jump Screen Test. The test itself required each athlete to step onto a 12-inch plyometric box. Next, the athlete stepped off the box, landed on both feet and immediately performed a vertical jump. Athletes were allowed to practice the Drop Jump Screen Test and demonstrate the ability to perform the test prior to evaluation.

Video recording of the Drop Jump Screen Test was used to analyze knee separation during the landing of the test. Prior to Block Zero training, athletes performed the Drop Jump Screen Test. Athletes also performed the Drop Jump Screen Test at the conclusion of the eight-week Block Zero training cycle. To account for a learning effect, each athlete performed the jump three times for both pre and post testing. Each athlete was recorded using an iPad. An average was determined from all three jumps. Video was uploaded to ImageJ software downloaded from https://imagej.nih.gov/ij/. Once the video was uploaded, a still image was used depicting the Drop Jump Screen Test at the lowest point of the landing to assess knee:ankle ratio. To measure knee:ankle ratio during the landing, the box size was measured in pixels on the screen and compared to the actual size of the box, then it was compared to the distance between knees in pixels and distance between ankles in pixels, then the pixels were correlated to inches.

Strength Testing. Four isometric exercises were tested pre and post intervention: single leg (SL) hip bridge for both legs, single leg (SL) lunge for both legs, body weight squat, and chin up hold. All exercises were performed for maximum time. The use of isometric strength exercises stems from the use and research regarding flex arm hang, which is utilized by the Fitnessgram and the United States Military as an assessment of upper body strength. Clemons, Duncan, Blanchard, Gatch, Hollander, and Doucet (2004) found the flex arm hang, or chin up hold, to be a reliable test to measure weight-relative strength. The results of the flex arm hang, an isometric contraction, as a viable method to develop relative strength supports the use of bodyweight exercises in Block Zero. The use of isometric contractions to measure strength is further supported by Earl and Hoch

(2011) who used isometric core holds for time to measure core strength and isometric contractions to measure hip adduction and abduction strength.

Statistical Analyses. Data were entered into SPSS to determine the difference in knee separation pre- and post-training for each participating athlete. Data were also entered into SPSS to determine the difference in strength pre- and post-training. A paired t-test was used to demonstrate change in knee:ankle ratio from pre- to post-intervention. Spearman's correlation was used to estimate strength of association between strength gains from SL hip bridge for both legs, SL lunge for both legs, and body weight squat with changes in knee:ankle ratio for both separation pre- and post-intervention.

Addition to Aim 1

This portion of the study required athletes within the last three years that have gone through Block Zero training to fill out a survey. Girls' soccer (GSOC), girls' volleyball (GVB), and girls' basketball (GBKB) head coaches called team meetings with tenth through twelfth graders where the purpose of the survey was explained. For athletes that were interested in doing the survey, home a letter of consent was sent home for their parents to give the athletes permission to fill out the survey. Once the athletes were chosen based on parental consent, surveys were distributed through email and asked surveys to be returned within two weeks.

Survey and Data Collection. The Knee Outcome Survey(KOS) Sport Activity Scale (SAS) (Table 6, Appendix E) was utilized to survey past participants of Block Zero on how symptoms effect sport activity and how the knee affects the ability to perform certain tasks during sport activities. Participants were instructed to reflect on Block Zero training and how they thought Block Zero training impacted their knee symptoms and the ability to perform tasks during sport activities.

The SAS is an 11 item survey that questions participants about how knee symptoms such as pain, grinding, stiffness, and weakness impact their ability to perform sports and recreational activities (Irrgang, Snyder-Mackler, Wainner. Fu, and Harner, 1998). The survey also assesses how knee condition effects the ability to perform specific sports related skills such as running straight ahead, jumping and landing on the involved leg, sudden stopping and starting, and cutting and pivoting (Irrgang et al., 1998).

Originally, the survey was used to learn about current perceptions of Block Zero training. In an attempt to capture available comparative information, it seemed useful to collect data with the survey on perceptions prior to starting Block Zero training to see if any interesting differences existed between perceptions before and after testing.

The survey has a total of 11 questions with 6 possible responses. From left to right response values are 5 (not difficult at all), 4, 3, 2, 1, 0 (unable to do). The point values are added together and divided by 55 and multiplied by 100 for the SAS score. Higher levels of sports and recreational function are associated with higher percentage ratings (Irrgang et al,. 1998). Differences between each survey score were calculated to determine a total number of positive, negative, or no change scores. McNemar's test for correlated proportions was used test the difference between positive and negative changes in survey responses.

Specific Aim 2

Data Collection of ACL Injury Rates. To determine the effect of Block Zero on incidence of ACL injury compared to past ACL injury incidence rates on those not trained with Block Zero, data collection occurred in three different areas. ACL Injury data were gathered from the athletic training staff at the host high school on teams that have been trained with Block Zero over the last four years: girls' basketball (GBKB), girls' volleyball (GVB), and girls' soccer (GSOC). The total number of athletes for each sport for each year was also requested. Email correspondence was sent to three area high school athletic trainers asking for permission to use ACL injury data for GBKB, GVB, and GSOC, as well as the total number of athletes for each year. Permission was granted and a request was sent to school administration to use unidentifiable information for ACL injury data. Once data were collected, confidence intervals were used to compare injury rates for each sport at each school.

Results

Specific Aim 1

Results of Aim 1 indicate a statistically significant difference in knee:ankle ratio during the initial landing of the drop jump screen test from pre to post intervention; $t(12)=-4.543$, $p<.001$. On average, knee:ankle ratio increased from pre (.887) to post (1.148) (Table 7, Appendix F). Strength was also measured from pre to post intervention. On average, each exercise tested increased from pre to post (Table 6, Appendix E). Single leg lunge increased from 22.615 seconds to 31.385 seconds on the left leg and 24.308 seconds to 33.462 seconds on the right leg. Single leg glute bridge increased from

23.077 seconds to 32.846 seconds on the left leg and 25.308 seconds to 36.000 seconds on the right leg. An increase from 33.000 seconds to 44.077 seconds was observed for the body weight squat hold.

Aim 1 also examined the relationship between increases in knee:ankle ratio and increases in strength. For each exercise tested, the correlation was found to be statistically significant at the .001 level (Table 8, Appendix G). Correlational evidence indicated an increase in knee:ankle ratios are positively related to increases in strength.

Addition to Aim 1

To support Aim 1, the Knee Outcome Survey (KOS) Sport Activity Scale (SAS) was used to determine perceptions from athletes that had previously participated in Block Zero. Participants were asked to complete the survey twice. The first survey was completed for current perceptions of Block Zero. The second survey was completed asking the participants to recall perceptions prior to starting Block Zero. Statistical findings indicate participants were more likely to report a positive effect of the program ($p=0.026$).

Specific Aim 2

Aim 2 utilized confidence intervals to compare ACL injury rates at the host high school with injury rates at three area high schools (Table 9, Appendix H). Confidence intervals for injury rates from each sport at the three area high schools compared to the host school showed that the proportion could be either higher or lower, therefore, it cannot be concluded statistically that the proportion of injuries at the host school would be higher than the other schools. However, injury rates were consistently higher at the other three schools regardless of sport except girls volleyball, where two schools reported zero injuries (Table 10, Appendix H).

Implications

Block Zero is a widely used introductory strength training program. However, to date, research on Block Zero is lacking. While current ACL injury prevention programs have documented success in reducing the incidence of injury in females, they remain more than two times as likely to sustain an ACL injury compared to males (Stanley et al., 2016). Valgus collapse has been suggested as a risk for ACL injury.

Participants of the Block Zero intervention underwent eight weeks of an introductory strength training program that placed an emphasis on relative strength training following progressive overload and jumping mechanics. Contrary to current ACL injury prevention programs, Block Zero does not employ the use of plyometric training. *Sportsmetrics* (Table 1, Appendix A) appears to utilize numerous rounds of plyometrics for time. Analysis of the *PEP* program (Table 2, Appendix B) illustrates low impact plyometrics, however, while there is mention of how important the landing is from jumping, exercises do not indicate an emphasis on mastery of the landing prior to jump training. The same can be said for *FIFA 11+* (Table 3, Appendix C) where plyometrics are utilized. *The FIFA 11+* manual discusses in great detail proper body alignment and knee alignment during plyometric training, however, exercises of the program do not reflect introduction of proper position or mastery of proper position prior to jump training (FIFA, 2007). Rather, Block Zero places an emphasis on jumping and landing mechanics and establishing a strength foundation prior to implementing plyometric training. Block Zero also employs progressive overload from cycle one to cycle two. The increases in knee:ankle ratio may be attributed to the use of relative strength exercises and the emphasis on jumping mechanics.

There are future implications based on the outcome of Aim 1 of this study. Noyes and Westin (2012) suggested a plethora of varying ACL injury prevention programs have been established to address ACL injuries, however, Yoo et al. (2010) found that plyometric and strength training are necessary factors for ACL injury prevention programs. In contrast to You et al. (2010), Davies et al. (2015) presented that exposing athletes to plyometric training before a foundational strength base is developed is inadvisable. Relative hip abduction strength (Brent et al., 2005) and core strength (Earl and Hoch, 2011) have been suggested as possible factors for increased ACL injury risk.

Results of Aim 1 of this study suggest that Block Zero may have an effect on valgus collapse by increasing the knee:ankle ratio during high impact moments. Block Zero programming appears to support Davies et al. (2015) through development of foundational strength prior to plyometric training. Taylor et al. (2015) reported that injury prevention programs do not utilize common strength training guidelines such as progressive overload. Block Zero programming illustrates progressive overload from cycle one to cycle two which separates IT from current injury prevention programs that do not employ progressive overload.

Block Zero programming provides exercises that target relative hip strength and core strength supporting Brent et al. (2005) and Earl and Hoch (2011). Positive increases in relative strength testing in the present study appear to complement the Earl and Hoch (2011) work.

The above information supports that the outcomes of Aim 1 may potentially impact future ACL injury prevention programs by demonstrating the need to employ progressive overload and the need to establish a strength foundation prior to starting plyometric training. Increases in relative strength are also worth noting and may be related to increased knee:ankle ratio during high impact moments. Findings suggest that a strong linear positive relationship exists between increased strength gains from the exercises measured and increased knee:ankle ratio (Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Appendix J).

Results of Aim 1 also reinforce anecdotal evidence from strength professionals who have experience implementing Block Zero. They have indicated Block Zero has had a positive effect on relative strength, jumping mechanics and reducing ACL injuries (B. Cundiff, A. Feit, personal communication, November 23, 2016). While a limiting factor of the study was the lack of a control group, results of this study warrant replication study with better control to determine the effects of Block Zero training on ACL injury risk factors.

Participants who completed the KOS SAS on average reported positive perceptions of Block Zero training. Eisner, Elder, Sinclair-Elder and Kelly (2014) examined the importance of strength and conditioning on increased athletic performance in college athletes through the use of a survey. Addition to Aim 1 results indicated athletes believed strength and conditioning was important to the overall development of athletic performance. This included a perception that strength and conditioning helps prevent injuries. Low motivation to implement injury prevention programs is a common barrier reported by Bogardus (2013). Kiani, Hellquist, Ahlqvist, Gedeborg, Michaelsson, and Byberg (2010) reported thirty six coaches declined to implement injury prevention programs due to skepticism about the effectiveness of the program. Results from aim one and positive perceptions toward strength and conditioning having a positive effect on injury prevention may offer support to strength professionals and coaches to implement Block Zero.

When compared to other schools, the host school demonstrated a lower injury rate with the exception of girls' volleyball. The results of Aim 2 were not calculated using the standard of strictly comparing ACL injuries to athlete exposures. Due to the unavailability of data, the total number of ACL injuries for each sport over a four year period compared to the total number of athletes over a four year period was utilized to calculate a ratio of ACL injuries. While results of Aim 2 were not significant, they do suggest that athletes at the host school may have experienced a lower ratio of ACL injuries as compared to the other schools. Results of Aim 2 seem to imply that Block Zero trained athletes may have had less chance of sustaining an ACL injury.

If the above holds true in future studies, Block Zero training could have an impact on reducing pain and suffering for numerous young athletes by reducing the rate of ACL injury. Curbing the rate of ACL injury can also impact the financial burden associated with ACL injury (Hewett and Johnson, 2010). ACL injuries can have devastating effects on athletes: loss of playing time, loss of scholarships, season ending injuries, and the onset of osteoarthritis (Hewett and Johnson, 2010). Block Zero training could impact the way in which strength and conditioning professionals train younger athletes, therefore, alleviating or curbing the devastating effects of ACL injuries.

CHAPTER II

DISSEMINATION

Dissemination for this study is in the form of a journal article. The article will be submitted to *The Athletic Training and Sport Health Care (ATSHC) Journal* for review upon completion of the dissertation project. The *ATSCH* was chosen due to the variety of professional fields that have access to the journal: athletic trainers, exercise physiologists, and strength and conditioning professionals.

Introduction

As early as 1983, research indicated a rising trend in anterior cruciate ligament (ACL) injuries where eighty percent of injuries are caused by non-contact mechanisms (Noyes, Mooar, and Matthews, 1983). A sixteen-year epidemiological study (1988-2004) presented by the National Collegiate Athletic Association (NCAA) showed that female gymnasts suffered an incidence of ACL injuries in .33 per 1000 athlete exposures and that three of the four sports with the highest incidence of ACL injuries were female sports: gymnastics, basketball, and soccer. A more recent eight-year epidemiological study from 2004-2005 to 2012-2013 indicates that when compared to male soccer players, females have .10 rate of injury (per 1,000 exposures) compared to males which is a .03 rate of injury (Agel et al, 2016). Similar results were found for basketball where females have .22 rate of injury compared to .08 for males, and for lacrosse where females have a .23 rate of injury compared to .13 for males (Agel et al. 2016).

The high incidence of ACL injury and the increased rate of injury for females has led researchers to develop ACL injury prevention programs that focus on neuromuscular and biomechanical risk factors, as they are considered modifiable risk factors (Voskarian, 2013). A key risk factor associated with non-contact ACL injuries in females that these programs have targeted is knee valgus. Hewett, Myer, Ford, and Heidt (2005) conducted an injury surveillance study and found that subjects that suffered non-contact ACL injuries demonstrated significant increases in lower extremity valgus and knee abduction. In a video analysis of 39 basketball ACL injuries, Krosshaug, Nakame, Boden, Engebretsen, Smith, Slauterbeck, Hewett, and Bahr (2007) found female basketball players demonstrated a 5.3 times higher relative risk of sustaining a valgus collapse at the time of injury when compared to male basketball players. Injury prevention programs that have focused on neuromuscular and biomechanical risk factors have documented success in reducing the rate of non-contact ACL injury (Hewett, Lindenfeld, Riccobene and Noyes, 1999; Mandelbaum, Silvers, Watanabe, Knarr, Thomas, Griffin, Kirkendall, and Garrett, 2005; Myer, Ford, Palumbo and Hewett, 2005).

Despite the efforts of current ACL injury prevention programs to address neuromuscular and biomechanical risk factors, a gender difference in ACL injury rates still exists for females when compared to males. Stanley, Kerr, Dompier, and Padua (2016) indicate females remain two times as likely to sustain an ACL injury when compared to males that compete in the same sport. Noyes and Westin (2012) suggest a variety of ACL injury prevention programs have been developed to address ACL injuries, however, the components of intervention programs vary tremendously. Noyes and

Westin (2012) found programs typically include plyometrics and agility exercises; however, only three programs implemented strength training: *Sportsmetrics*, *PEP*, and the *FIFA 11* (Noyes and Westin, 2012). Intensity and duration of programs range from 15 to 120 minutes and programs have been implemented during the season and prior to the start of the athletic season starting (Noyes and Westin, 2012). Yoo, Lim, Ha, Lee, Oh, Lee, and Kim (2010) conducted a meta-analysis on the effect of neuromuscular training on the prevention of ACL injuries in female athletes and found that while a certain combination of neuromuscular and biomechanical components could not be verified, plyometric and strength training are necessary factors for a prevention program.

However, a recent systematic review indicated that injury prevention programs often do not employ common strength training guidelines such as progressive overload (Taylor et al., 2015). Furthermore, Davies, Reimann, and Manske (2015) indicated the most significant contraindication to plyometric training is exposing the athlete to plyometrics before a foundational strength base is developed.

Current ACL injury prevention programming that have included strengthening and plyometrics are reported to be effective in reducing ACL injury rates (Voskanian, 2013); despite the fact the programs do not employ suggested strength training guidelines or the development of relative strength. If strength training is a critical element of these programs, developing programs that adhere to progressive overload and the development of foundational strength prior to plyometric training, as well the development of relative strength should yield more effective injury reduction.

Purpose Statement

The purpose of this program evaluation is to examine both objective and athlete perceived biomechanical outcomes of Block Zero training thought to be associated with ACL injury risk potential. The central hypothesis, which is based on prior strength training literature and observational experiences with Block Zero, was that athletes who increase strength in response to their Block Zero training will increase knee separation distance (a 2-dimensional measure of bi-lateral knee valgus collapse between) during the high impact landing of the Drop Jump Screen Test, and that athletes who have participated in block zero in the past will report that Block Zero has had a positive impact on jumping mechanics, and will report fewer ACL injuries than athletes that did not participate in Block Zero. The rationale for this study was that demonstrating the implementation of proper strength training protocols which may positively impact knee valgus, future ACL prevention programs will be more effective at reducing the sex-disparity in ACL injuries. Block Zero is a widely implemented program in collegiate and high school strength settings, however, Block Zero has yet to be studied. The ***specific aims*** are:

Specific Aim 1: Identify the extent to which Block Zero Training increased the knee:ankle ratio during performance of the Drop Jump Screen Test landing. The working hypothesis was that Block Zero training would increase the knee:ankle ratio during the performance of the Drop Jump Screen test landing from pre- to post- test.

Addition to Aim 1: Determine perceived benefits of Block Zero training through an exploration of knee symptoms and an ability to perform certain tasks during sport participation in past participants of Block Zero. It was hypothesized that past participants of Block Zero would have a positive perception of Block Zero concerning knee symptoms and certain maneuvers during sport participation

Specific Aim 2: To conduct an exploratory analyses of injury data to determine if athletes who participated in Block Zero were less susceptible to ACL injury than those who did not participate in Block Zero. The working hypothesis was that athletes that did not participate in Block Zero would incur more ACL injuries than athletes who participated in Block Zero.

Results of this program evaluation may result in further evaluation of current ACL injury prevention programs implemented by physical therapists and athletic trainers. Researchers in the field of exercise science, athletic training, and biomechanics that study and suggest protocols may also see value in future research on Block Zero. Strength and conditioning professionals that work with female athletes on a daily basis may have a keen interest in protocols that can help reduce the rate of non-contact ACL injury.

Methods

Specific Aim 1

The sample for the study were 9th grade female athletes from multiple sports. All freshmen athletes were exposed to Block Zero training. All athletes in this preliminary study received Block Zero training. It seemed unwise, and possibly unethical, to use a control group in which athlete would not receive Block Zero training before more is known about this type of training. Prior to beginning the program, participants were given parent permission forms and consent forms approved by the Institutional Review

Board (IRB) at the University of North Carolina at Greensboro. Only those with parent permission and consent forms were included in the results of the study. Block Zero serves as a foundational strength training program, therefore, these participants were chosen due to their novice experience in strength and conditioning. The sports represented among the participants were girls volleyball, girls softball, girls basketball and girls soccer. There were a total of 13 participants that were included in the reporting of results.

Block Zero Training. The Block Zero program utilized in this study was derived from Coach Joe Kenn (2016). The eight week program follows periodization guidelines defined by the NSCA. Periodization cycles are defined as macro (typically a year), meso (several weeks to several months), and micro (one to four weeks) (Baechle and Earle, 2008). The Block Zero program represents an eight week mesocycle that is divided into two four week microcycles (Table 4, Table 5, Appendix D). The athletes participated for 45 minute sessions three days per week. The daily program was divided into four areas: athletic position, jumping mechanics, stabilization, and relative strength. The eight-week program was divided into two four week phases.

Phase two progressed in intensity reflecting the principle of progressive overload. Exercises increased in repetitions or by adding time. The athletic position aspect area of the program placed an emphasis on the power position and landing position. During the jumping mechanics portion of the program, athletes were introduced to low intensity plyomtetrics. Prescription of repetitions for plyometrics were well below the recommendations set forth by the NSCA for novice athletes (3 sets of 6 for a total of 18 foot contacts). Stabilization refers to isometric strength. Participants of Block Zero performed upper and lower body exercises and held the isometric contraction for prescribed time.

The final area, relative strength, placed the athlete through upper and lower body exercises without an external load. Intensity was manipulated through reps, time, and tempo. Athletes performed five isometric exercises for time during pre and post training to measure increases in isometric strength: chin up hold, isometric push up, isometric single leg glute bridge, isometric split squat, and isometric squat.

Drop Jump Screen Test. Before an athlete could complete the Drop Jump Screen Test, she had to first understand how to perform the Drop Jump Screen Test. The test itself required each athlete to step onto a 12-inch plyometric box. Next, the athlete stepped off the box, landed on both feet and immediately performed a vertical jump. Athletes were allowed to practice the Drop Jump Screen Test and demonstrate the ability to perform the test prior to evaluation.

Video recording of the Drop Jump Screen Test was used to analyze knee:ankle ratio during the landing of the test. Prior to Block Zero training, athletes performed the Drop Jump Screen Test. Athletes also performed the Drop Jump Screen Test at the conclusion of the eight-week Block Zero training cycle. To account for a learning effect, each athlete performed the jump three times for both pre and post testing. Each athlete was recorded using an iPad. An average was determined from all three jumps. Video was uploaded to ImageJ software downloaded from https://imagej.nih.gov/ij/. Once the video was uploaded, a still image was used depicting the Drop Jump Screen Test at the lowest point of the landing to assess knee separation. To measure knee:ankle ratio during the landing, the box size was measured in pixels on the screen and compared to the actual size of the box, then it was compared to the distance between knees in pixels and ankles in pixels, then the pixels were correlated to inches.

Strength Testing. Four isometric exercises were tested pre and post intervention: single leg (SL) hip bridge for both legs, single leg (SL) lunge for both legs, body weight squat, and chin up hold. All exercises were performed for maximum time. The use of isometric strength exercises stems from the use and research regarding flex arm hang, which is utilized by the Fitnessgram and the United States Military as an assessment of upper body strength. Clemons et al. (2004) found the flex arm hang, or chin up hold, to be a reliable test to measure weight-relative strength. The results of the flex arm hang, an isometric contraction, as a viable method to develop relative strength supports the use of bodyweight exercises in Block Zero. The use of isometric contractions to measure strength is further supported by Earl and Hoch (2011) who used isometric core holds for time to measure core strength and isometric contractions to measure hip adduction and abduction strength.

Addition to Aim 1

This portion of the study required athletes within the last three years that have gone through Block Zero training to fill out a survey. Girls soccer (GSOC), girls volleyball (GVB), and girls basketball (GBKB) head coaches called team meetings with tenth through twelfth graders. I will attend the meeting and explain the purpose of the survey. For athletes that are interested in doing the survey, I will send home a letter of consent for their parents to give the athletes permission to fill out the survey. Once the athletes were chosen based on parental consent, I distributed the survey through email and asked surveys to be returned within two weeks.

Survey and Data Collection. Survey and Data Collection. The Knee Outcome Survey(KOS) Sport Activity Scale (SAS) (Table 6, Appendix E) was utilized to survey past participants of Block Zero on how symptoms effect sport activity and how the knee affects the ability to perform certain tasks during sport activities. Participants were instructed to reflect on Block Zero training and how they thought Block Zero training impacted their knee symptoms and the ability to perform tasks during sport activities.

The SAS is an 11 item survey that questions participants about how knee symptoms such as pain, grinding, stiffness, and weakness impact their ability to perform sports and recreational activities (Irrgang, Snyder-Mackler, Wainner. Fu, and Harner, 1998). The survey also assesses how knee condition effects the ability to perform specific sports related skills such as running straight ahead, jumping and landing on the involved leg, sudden stopping and starting, and cutting and pivoting (Irrgang et al., 1998).

Originally, the survey was used to learn about current perceptions of Block Zero training. In an attempt to capture available comparative information, it seemed useful to collect data with the survey on perceptions prior to starting Block Zero training to see if any interesting differences existed between perceptions before and after testing.

The survey has a total of 11 questions with 6 possible responses. From left to right response values are 5 (not difficult at all), 4, 3, 2, 1, 0 (unable to do). The point values are added together and divided by 55 and multiplied by 100 for the SAS score. Higher levels of sports and recreational function are associated with higher percentage ratings (Irrgang et al,. 1998). Differences between each survey score were calculated to determine a total number of positive, negative, or no change scores. McNemar's test for correlated proportions was used test the difference between positive and negative changes in survey responses.

Specific Aim 2

Data Collection of ACL Injury Rates. To determine the effect of Block Zero on incidence of ACL injury compared to past ACL injury incidence rates on those not trained with Block Zero, data collection occurred in three different areas. I worked with the athletic training staff at the host high school to gather ACL injury data on teams that have been trained with Block Zero over the last four years: girls basketball (GBKB), girls volleyball (GVB), and girls soccer (GSOC). The total number of athletes for each sport for each year will also be requested. Email correspondence was sent to three area high school athletic trainers asking for permission to use ACL injury data for GBKB, GVB, and GSOC, as well as the total number of athletes for each year. Permission was granted and a request was sent to school administration to use unidentifiable information for ACL injury data.

Results

Specific Aim 1

Aim 1 examined the difference in knee:ankle ratio during the initial landing of the drop jump screen test from pre to post intervention and measured the difference in isometric strength movements from pre to post intervention. A paired t-test was used to demonstrate change in knee:ankle ratio and strength changes from pre- to post-intervention. Spearman's correlation was used to estimate strength of association between strength gains from SL hip bridge for both legs, SL lunge for both legs, and body weight squat with changes in knee for both separation pre- and post-intervention. To account for a learning effect of the Drop Jump Screen test, each athlete performed the Drop Jump Screen Test three times and an average was calculated for the three jumps.

Results of Aim 1 indicate a statistically significant difference in knee:ankle ratio from pre to posttest; $t(12)=-4.543$, $p<.001$ (Table 6, Appendix E). On average, knee:ankle ratio increased from pre (.887) to post (1.148). Subject 9 was the only subject that did not have increases in knee:ankle ratio from pre (1.013) to post (0.987). Strength was also measured from pre to post intervention. On average, each exercise tested increased from pre to post (Table 6, Appendix E). Single leg lunge increased from 22.615 seconds to 31.385 seconds on the left leg ($t(12)=-13.658$, $p<.001$) and 24.308 seconds to 33.462 seconds on the right leg ($t(12)=-11.338$, $p<.001$). Single leg glute bridge increased from 23.077 seconds to 32.846 seconds on the left leg ($t(12)=-11.834$, $p<.001$) and 25.308 seconds to 36.000 seconds on the right leg ($t(12)=-11.956$, $p<.001$). An increase from 33.000 seconds to 44.077 seconds was observed for the body weight squat hold ($t(12)=-12.000$, $p<.001$).

Aim 1 also examined the relationship between increases in knee:ankle ratio and increases in strength. For each exercise tested, the correlation was found to be statistically significant at the .001 level (Table 7, Appendix F).

Addition to Aim 1

To support Aim 1, the Knee Outcome Survey (KOS) Sport Activity Scale (SAS) was used to determine perceptions from athletes that had previously participated in Block Zero. Participants were asked to complete the survey twice. The first survey was completed for current perceptions of Block Zero. The second survey was completed asking the participants to recall perceptions prior to starting Block Zero. Even though these were recall data, they were deemed interesting in support of aim one results. McNemar's test for correlated proportions was used to test for differences between positive and negative changes in survey responses.

A total of 33 responses were recorded from the first survey distribution. There were twenty four responses from the second survey distribution. For the purposes of statistical analysis, only participants that responded for both survey distributions were used, a total of twenty four. Sixteen participants reported a positive perceived benefit (66.6%), six reported a negative perceived benefit, and two reported no change. Statistical analysis indicated participants were more likely to report a positive effect of the program ($p=0.026$).

Specific Aim 2

Aim 2 utilized confidence intervals to compare ACL injury rates at the host high school with injury rates at three area high schools among girls basketball, girls volleyball, and girls soccer (Table 9, Appendix H). Confidence intervals for injury rates from each sport at the three area high schools compared to the host school showed that the proportion could be either higher or lower, therefore, it cannot be concluded statistically that the proportion of injuries at the host school would be higher than the other three schools. However, injury rates were consistently higher at the other three schools regardless of sport except girls volleyball, where two schools reported zero injuries (Table 10, Appendix H).

Ratios were calculated based on injured athletes of athletes over a four year period and the total number of athletes over a four year period for each sport. The host school demonstrated a 0.018 ratio of ACL injury in girls basketball compared to school two (.020), school three (.037) and school four (.031). Girls soccer ratios were also higher at school two (.030), school three (.018), and school four (.022) compared to the host school (.011). The injury ratio for volleyball at the host school (.007) was lower than school three (.027), however, both school two and school four reported zero ACL injuries for girls volleyball over the last four years.

Discussion

Specific Aim 1

Results of this program evaluation indicate that participants experienced increased knee:ankle ratio separation from pre to post test, as well as increased relative strength from pre to post test. Correlational evidence indicates that a positive increase in strength may result in a positive increase in knee:ankle ratio. Prior research indicates that females are at greater risk of ACL injury due to decreased flexion and an increase in knee valgus (Campbell et al, 2014). Video analysis conducted by Krosshaug et al. (2007) found that female basketball players demonstrated a 5.3 times higher relative risk of sustaining a valgus collapse at the time of injury when compared to male basketball player. While a direct casual effect cannot be established due to the lack of a control group, results suggest that Block Zero may have had a positive impact on knee:ankle ratio and a positive impact on strength.

In a study designed to examine the effects of a strengthening program on patellofemoral pain syndrome (PFPS), Earl and Hoch (2011) found that strengthening and improving neuromuscular control of the hip and core musculature improved hip and core strength, as well as reducing the knee abduction moment. Participants in the Block Zero program participated in various exercises that focused on the development of relative strength of the hips and core musculature. Findings indicated that a strong linear positive relationship exists between increased strength gains from the exercises measured and increased knee:ankle ratio (Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Appendix J). These results address Aim 1 and are supported by Earl and Hoch (2011) with increased knee:ankle ratios and increases in relative strength, however, due to the nature of this study, future research is needed to confirm this relationship between relative strength and knee:ankle ratio using larger groups of participants.

Addition to Aim 1

The results of the KOS SAS (Sub Aim 1) indicated Block Zero may have had a positive effect on perceived biomechanical outcomes based on participant responses. Participants who completed the KOS SAS on average reported positive perceptions of Block Zero training. Eisner, Elder, Sinclair-Elder and Kelly (2014) examined the importance of strength and conditioning on increased athletic performance in college athletes through the use of a survey. Results meant to address Sub-Aim 1 indicated athletes believed strength and conditioning was important to the overall development of athletic performance. This included a perception that strength and conditioning helps prevent injuries. Low motivation to implement injury prevention programs is a common barrier reported by Bogardus (2013). Kiane et al. (2010) reported thirty six coaches declined to implement injury prevention programs due to skepticism about the effectiveness of the program. Test Results from Aim 1 and positive perceptions toward strength and conditioning having a positive effect on injury prevention may offer a reason for strength professionals and coaches to implement A Block Zero training program.

Specific Aim 2

Results addressing Aim 2 suggest the host school demonstrated a lower injury rate with the exception of girls volleyball compared to other schools. These results were not calculated using the standard of strictly comparing ACL injuries to athlete exposures as used in previous studies (Agel, Rockwood and Klossner, 2016; Hootman, Dick, and Agel, 2007; Renata et al., 2011). Due to the unavailability of data, the total number of athletes for each sport over a four year period compared to the number of ACL injuries over a four year period was utilized to calculate a ratio of ACL injuries. While results addressing Aim 2 were not significant, they do suggest that athletes at the host school may have experienced a lower ratio of ACL injuries as compared to the other schools. Further research is warranted using existing ACL injury rate exposure from various schools comparing those that use Block Zero training versus those that use other forms of training.

Conclusion

Results from this study suggest there was a strong relationship between increased relative strength and increased knee:ankle ratio during the performance of the Drop Jump Screen Test. Perceptions of past participants of Block Zero suggest positive perceptions of strength training may positively impact injury prevention. While results were not statistically significant when comparing injury ratios from the host school to area high schools, injury rates were consistently lower at the host school. Results of this study warrant future research which may suggest Block Zero training would be beneficial to reducing ACL injury rates in female athletes.

CHAPTER III
ACTION PLAN

Results of this program evaluation indicate that participants experienced increased knee:ankle ratio separation from pre to post test, as well as increased relative strength from pre to post test. Results also indicate Block Zero may have had a positive effect on perceived biomechanical outcomes based on participant responses. Participants who completed the KOS SAS on average reported positive perceptions of Block Zero training. Examination of injury ratios from this study suggest the host school demonstrated a lower injury ratio with the exception of girls volleyball compared to other schools.

While results of this study are preliminary in nature, there are future implications based on the outcomes of this program evaluation. Results of Aim 1 of this study suggest that Block Zero may have an effect on valgus collapse by increasing the knee:ankle ratio during high impact moments. Block Zero programming reflects progressive overload from cycle one to cycle two supporting evidence from Taylor et al. (2015). Jumping mechanics are included in Block Zero programming; however, the emphasis of the program is the development of foundational strength prior to plyometrics reflecting Davies et al. (2015).

Participants who completed the KOS SAS on average reported positive perceptions of Block Zero training. Eisner, Elder, Sinclair-Elder and Kelly (2014) examined the importance of strength and conditioning on increased athletic performance in college athletes through the use of a survey. This included a perception that strength and conditioning helps prevent injuries. Results of Addition to Aim 1 indicated athletes believed strength and conditioning was important to the overall development of athletic performance. Low motivation to implement injury prevention programs is a common barrier reported by Bogardus (2013) and reflects the findings from Kiani et al. (2010), which reported thirty six coaches declined to implement injury prevention programs due to skepticism about the effectiveness of the program. Results from aim one and positive perceptions toward strength and conditioning having a positive effect on injury prevention may offer support to strength professionals and coaches to implement Block Zero.

When compared to other schools, the host school demonstrated a lower injury rate with the exception of girls volleyball. The results of Aim 2 were not calculated using the standard of strictly comparing ACL injuries to athlete exposures. Due to the unavailability of data, the total number of athletes for each sport over a four year period compared to the number of ACL injuries over a four year period was utilized to calculate a ratio of ACL injuries. While results of Aim 2 were not significant, they do suggest that athletes at the host school may have experienced a lower ratio of ACL injuries as compared to the other schools. Results of Aim 2 seem to imply that Block Zero trained athletes may have had less chance of sustaining an ACL injury.

If the above holds true in future studies, Block Zero training could have an impact on reducing pain and suffering for numerous young athletes by reducing the rate of ACL injury. Curbing the rate of ACL injury can also impact the financial burden associated with ACL injury (Hewett and Johnson, 2010). ACL injuries can have devastating effects on athletes: loss of playing time, loss of scholarships, season ending injuries, and the onset of osteoarthritis (Hewett and Johnson, 2010). Block Zero training could impact the way in which strength and conditioning professionals train younger athletes, therefore, alleviating or curbing the devastating effects of ACL injuries.

When constructing an action plan, it is important to consider current barriers to implementation of injury prevention programs to maximize adoption of Block Zero. The practical impact of injury prevention programs ultimately depends on efficacy, adoption, and implementation of the program (Obrien, Young, and Finch, 2016). A meta-analysis conducted by Bogardus (2013) found five barriers to implementation of ACL injury prevention programs: motivation, time requirements, skill requirements for program facilitators, cost, and compliance. The engagement of stakeholders is also suggested as a consideration for the implementation and adoption of injury prevention programs (Donaldson, Lloyd, Gabbe, Cook, and Finch, 2017).

There are several possible avenues to disseminate findings from this program evaluation for immediate impact: clinic presentations, journal article, and in-service sessions with physical education teachers within school district. There are also opportunities to present the results of this program evaluation that could have long-term effects: involvement with state athletic trainers and state high school associations, involvement with youth organizations and community organizations.

Clinic Presentations

The National Strength Coaches Association (NSCA) indicates that a key benefit of employing strength and conditioning coaches is to minimize the incidence and severity of youth sport related injuries (NSCA, 2016). Faigenbaum, Kraemer, Blimkie, Jeffreys, Micheli, Nitka, and Rowlan (2009) presented that a properly designed strength program can increases the strength of children, enhance motor skills, and prevent injuries. Results from this study would be of great interest to strength and conditioning professionals as they are charged with the goal to reduce injuries through sound strength programming. There are numerous opportunities within the strength and conditioning field to present findings from this study to strength and conditioning professionals. The NSCA offers both state, regional, and national strength and conditioning clinics yearly. Applications to speak at the NSCA National Conference are due by May 15th of each year. The Collegiate Strength and Conditioning Coaches Association (CSCCa) also has a national conference in May of each year that could serve as a possibility to present findings from this study. The process to speak at the CSCCa conference entails submitting a proposal via email to the CSCCa for review. There is not a specific deadline for submission, but it is encouraged to submit in a timely manner.

Opportunities to present at sport specific conferences would also be considered advantageous for immediate impact. In the high school setting, sport coaches decide what activities are implemented (Norcross, Johnson, Bovbjerg, Koester, and Hoffman, 2015), rather than a strength coach. Norcross et al. (2016) indicate that despite proven efficacy of injury prevention programs, high school coaches do not widely adopt injury prevention programs. To address possible barriers to implementation as presented by Bogardus (2013), and secure adoption among sport coaches, presentations would be centered on addressing motivation, time concerns, developing skills of the sport coach, and addressing concerns of cost. Prior research has found that education workshops can intensify a positive attitude toward the benefits of ACL injury prevention programs (Frank et al., 2015), which may increase a likelihood of compliance to implement Block Zero.

Glazier Clinics are a plausible platform to reach numerous sport coaches. Glazier Clinics are held nationwide and offer clinic workshops that directly reach football, volleyball, soccer, track and field, and athletic performance coaches. For the purpose of presenting results from this program evaluation, clinics that are centered on volleyball, soccer, and athletic performance would be considered. Clinics are held in various cities around the country from January to May. To be considered for a speaking engagement with a Glazier Clinic, a Google Doc is completed and submitted for consideration.

Journal Article

A key component of Block Zero is the practicality of the program and testing procedures. Block Zero consists of a plethora of exercises that do not require equipment or a weight room. An instrumental component of Block Zero programming is the focus of relative strength development. Testing procedures consist of body weight exercises to measure increases in relative strength, which do not require equipment to measure.

To illustrate the practicality of Block Zero, prior research must be considered that indicates the delivery and content of injury prevention programs must be designed to address different concerns: training formats, locations, and player ability levels (Obrien et al., 2017). As stated, a multitude of Block Zero exercises do not require equipment, however, where equipment is needed; cost analysis will be presented, as well as modifications to exercises to accommodate training locations, formats, and ability levels.

Publishing the results of this study would be a viable option of dissemination to demonstrate the practicality of Block Zero. *The Athletic Training and Sport Health Care (ATSHC) Journal* is one possible journal that has expressed interest in reviewing an article submission from this study. Upon completion of the dissertation requirements, the dissemination of findings will be formatted to meet the requirements set forth by *ATSHC* for submission to their double blind review process.

School District Implementation

As previously stated, the involvement of stakeholders may intensify the adoption of an injury prevention program (Donaldson et al., 2017). In the educational setting, key stakeholders important to the adoption of an injury prevention program would be considered administrators. Padua, Frank, Donaldson, de la Motte, Camerson, Beutler, DiStefano, and Marshall (2014) highlight seven steps to developing and implementing a preventive program, in which establishing administrative support is step one. To establish administrative support, findings from this study would be presented to administrators in a manner to reinforce the mission of the school district. As well present the adoption of Block Zero district wide may lead to a reduction in ACL injuries reducing the financial burden placed upon the school district due to ACL injuries.

A key component to establish administrative support will be to present a plan for implementation of Block Zero into the physical education curriculum at the middle school level. While participants of this study were ninth grade female athletes, the participants experienced increases in strength, which would be beneficial to all students that participate in physical education. As Block Zero is considered an introductory strength training program, implementing Block Zero in the middle school PE curriculum would align with the NSCA position statement on youth resistance training that highlights a properly designed resistance training program can improve the cardiovascular profile, improve motor skill performance, improve the psychosocial well being, and help promote exercise habits during adolescence of participants (Faigenbaum, Kraemer, Blimkie, Jefferys, Micheli, Nitka, and Rowland, 2009).

Upon district approval, in-service sessions will be required, during the week prior to school starting in August, with middle school physical education teachers to decide the best manner for implementation of Block Zero into the middle school PE curriculum. Similar to clinic presentations, adoption of Block Zero at the middle school level must address motivation, time concerns, development of skills of the PE teacher. *Fitnessgram* is used in all three middle schools, so it will be imperative to draw parallels to the strength training from Block Zero to the testing procedures of *Fitnessgram:* aerobic capacity, abdominal strength and endurance, trunk extensor strength and flexibility, upper body strength and endurance, and flexibility (Cooper Institute, 2014).

Consideration must also be given to current curriculum standards and teaching units. Adoption and implementation of Block Zero in middle school PE will only occur if PE teachers can find ways to include Block Zero into current teaching units or if inclusion of Block Zero does negatively impact achievement of curriculum standards. Preliminary discussions have occurred with current middle school PE teachers in the investigator's school district to gauge interest and thoughts on the inclusion of Block Zero. Currently PE programs in the school district implement "Fitness Fridays" where the focus is various fitness exercises geared toward establishing interest in endurance or strength training. Block Zero would coincide with "Fitness Fridays" as well as with current warm up times that are utilized on a daily basis in middle school PE.

To further ensure adoption and implementation of Block Zero in middle school PE programs in the school district, the in-service session must offer information and opportunity that allows the PE teachers to fully understand and fell comfortable with Block Zero. Bizzini, Junge and Dvorak (2013) found that coaches even though coaches have positive perceptions of implementing an injury prevention program, coaches did not believe in their capability to do so. Education programs must better equip coaches with skills and knowledge to implement injury prevention programs (Bizzini et al., 2013). In-service sessions will be centered on presenting results of the Block Zero program, as well offer hands on practical experiences so that school district PE teachers will have the confidence to implement Block Zero in the PE curriculum.

National Impact

Not only does an action plan need to have an immediate impact, but action plans should also have a global or larger encompassing impact. Preliminary results from this program indicate participants experienced positive increases in knee:ankle ratio, strength, and on average report positive experiences with exposure to Block Zero. Considering that females remain two times as likely to sustain an ACL injury (Stanley et al., 2016), results of this study may have a broader reach if governing sport associations adopt and support Block Zero.

Before Block Zero is supported and implemented from governing sport associations, Block Zero needs to be supported and recognized by the National Strength and Conditioning Association. The NSCA is the largest certifying body for strength professionals in the world. They offer two certifications in which Block Zero could become part of the certification process: Certified Strength and Conditioning Specialist and Certified Personal Trainer. Block Zero would reach an exponential number of people by becoming part of the certification process with the NSCA. When Saunders, Otago, Romiti, Donaldson, White, and Finch (2010) examined the implementation of an injury prevention program in junior community netball, it was suggested that including the injury prevention program into existing workshops and accreditation courses would be most appropriate to encourage implementations. Inclusion of Block Zero in the NSCA certification process would not only be available to all certified strength professionals, but would also be a pragmatic approach to encourage implementation.

With the support of the NSCA, another possible avenue for the findings of the program evaluation is the National Federation of State High School Associations (NFHS) The NFHS serves state high school associations by establishing standards and rules for sport, as well providing support and improving the experience for participants (NFHS Mission Statement, 2017). Within the NFHS website, NFHS offers NFHSlearn.com which offers a multitude of courses that can be take online. A specific course that is offered online through NFHSlearn.com is a strength and conditioning course. This course is presented by the NSCA and would be an outlet to disseminate information about Block Zero.

The process to enact the outlined plan would require future research on Block Zero to continue under an experimental design. With the expectation that results would remain consistent, to garnish support from the NSCA, journal articles will be presented for review in the *Journal of Strength and Conditioning*, as well information will be given to Special Interest Groups (SIG) within the NSCA. SIGs exist for various sports and levels of coaches (college and high school). Inclusion of Block Zero in SIGs would ensure information is distributed to all members of the SIG as well as interested coaches or trainers for the sports.

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APPENDIX A

SPORTSMETRICS

Table 1

Sportsmetrics. Hewett et al. (1999)

Phase 1 Wall Jumps Tuck Jumps Broad jumps stick (hold) Landing Squat Jumps Double legged cone jumps 180 degree jumps Bounding in place	Week 1 20 Sec 20 Sec 5 Reps 10 Sec 30sec/30 Sec 20 Sec 20 Sec	Week 2 25 Sec 25 Sec 10 Reps 15 sec 30sec/30sec (side to side and back to front) 25 sec 25sec
Phase II: Fundamentals Wall Jumps Tuck Jumps Jump, jump, jump, vertical Jump Squat Jumps Bounding for distance Double legged cone jumps Scissors jump Hop, hop, stick landing	Week 3 30 Sec 30 Sec 5 reps 20 sec 1 run 30sec/30sec 30 sec 5 reps/leg	Week 4 30 sec 30 sec 8 reps 20 sec 2 runs 30 sec/30 sec (side to side and back to front) 30 sec 5 reps/leg
Phase III: Performance Wall Jumps Step, jump up, down, vertical Mattress jumps Single-legged jumps distance Squat jumps Jump into bounding Hop, hop, stick landing	Week 5 30 sec 5 reps 30sec.30sec 5 reps/leg 25 sec 3 runs 5 reps/leg	Week 6 30 sec 10 reps 30 sec/30 sec (side to side and back to front) 5 reps/leg 25 sec 4 runs 5 reps/leg

APPENDIX B

PREVENT INJURY AND ENHANCE PERFORMANCE

Table 2

Prevent Injury and Enhance Performance. Gilchrist et al. (2008)

Warm Up	Jog to line of soccer field, shuttle run, backward running
Stretching	30seconds x 2 reps each: calf stretch, quadriceps stretch, inner thigh stretch, hip flexor stretch
Strength	Walking lunges (20 yard x 2), Russian Hamstring (3 x 10), Single toe-raise (30 Reps ea. Side)
Plyometrics	Lateral hops over 2 to 6 inch cone, forward/backward hops over 2 to 6 inch cone, single leg hops over 2 to 6 inch cone, vertical jumps w/ headers, scissors jump
Agilities	Shuttle run with forward/backward running (40 yards), diagonal run (40 yards), bounding run (45-50 yards)

APPENDIX C

FIFA 11+

Table 3

FIFA 11+. FIFA (2007).

I. Running exercises, 8 minutes (opening warm up, in pairs; course consists of 6-10 pairs of parallel cones)	
Running straight ahead	x 2
Running hip out	x 2
Running hip in	x 2
Running circling	x 2
Running and jumping	x 2
Running quick run	x 2
II. Strength, plyometrics, balance, 10 minutes (one of three exercise progression levels each training session)	
The Plank:	
Level 1: Both Legs	3 x 20-30 seconds
Level 2: Alternate legs	3 x 20-30 seconds
Level 3: one leg lift	3 x 20-30 seconds
Side Plank:	
Level 1: Static	3 x 20-30 seconds (each side)
Level 2: Dynamic	3 x 20-30 seconds (each side)
Level 3: with leg lift	3 x 20-30 seconds (each side)
Nordic Hamstrings:	
Level 1	x 3-5
Level 2	x 7-10
Level 3	x 12-15
Single Leg Balance	
Level 1: holding ball	2 x 30 seconds (each leg)
Level 2: throwing ball to partner	2 x 30 seconds (each leg)
Level 3: testing partner	2 x 30 seconds (each leg)
Squats:	
Level 1: with heel raised	2 x 30 seconds
Level 2: walking lunges	2 x 30 seconds
Level 3: one leg squats	2 x 10 (each leg)

Jumping: Level 1: vertical jumps Level 2: lateral jumps Level 3: box jumps	 2 x 30 seconds 2 x 30 seconds 2 x 30 seconds
III. Running exercises, 2 minutes (final warm up)	
Running over pitch Bounding run Running and cutting	x 2 x 2 x 2

APPENDIX D

BLOCK ZERO

Table 4

Block Zero Cycle 1. Kenn (2008).

Day 1	Day 2	Day 3
	Athletic Position	
Athletic Position Hold x 30 Seconds x 3	Athletic Position Hold x 30 Seconds x 3	Athletic Position Hold x 30 Seconds x 3
Athletic Position to Squat x 5	Athletic Position to Squat x 5	Athletic Position to Squat x 5
Athletic Position to Goodmorning x 10	Athletic Position Lateral Lunge x 3e	Athletic Position to Abduction/Adduction x 10
	Jumping Mechanics Circuit--3 Rounds	
Athletic Position Snap Down x 6	Athletic Position Snap Down x 6	Athletic Position Snap Down x 6
Athletic Position to VJ w/ Stick x 6	Athletic Position to Long Jump w/ Stick x 6	Altitude Drop from 6inch Box w/ Stick x 6
	Stabilization Circuit--3 Rounds	
Back Extension Hold x 30sec	Back Extension Hold x 30 Sec	Back Extension Hold x 30 Sec
Counter Balance Squat x 30sec	Lunge Hold x 15sec. Each Leg	Lateral Lunge Hold x 15sec. Each Leg
Chin Up/Inverted Row Hold x 15 Sec	Push Up Hold x 15sec.	Chin Up/Inverted Row x 15sec.
Front Plank x 30s	Front Plank x 30s	Front Plank x 30s
	Relative Strength Circuit--3 Rounds	
Back Extension x 10	Reverse Lunge x 6e	Russian Hamstrings x 8
Counter Balance Squat x 10	Counter Balance Squat x 10	Counter Balance Squat x 10
Chin Up/Inverted Row x 10	Push Up x 10	Chin Up/Inverted Row x 10
Double Leg Hip Hinge x 10	Flat Footed Sit Up x 10	SL Hip Hinge x 10e

Table 5

Block Zero Cycle 2. Kenn (2008).

Day 1	Day 2	Day 3
	Athletic Position	
Athletic Position Hold x 30 Seconds x 3	Athletic Position Hold x 30 Seconds x 3	Athletic Position Hold x 30 Seconds x 3
Athletic Position to Squat x 5	Athletic Position to Squat x 5	Athletic Position to Squat x 5
Athletic Position to Goodmorning x 10	Athletic Position Lateral Lunge x 3e	Athletic Position to Abduction/Adduction x 10
	Jumping Mechanics Circuit--3 Rounds	
AP to Long Jump then Vertical w/ Stick x 3	AP to VJ then LJ w/ Stick x 3	AP to Three Jump w/ Stick x 2
Altitude Drop from 12 inch box w/ stick x 6	Altitude Drop from 12 inch box w/ stick x 6	Altitude Drop from 12 inch box w/ stick x 6
	Stabilization Circuit--3 Rounds	
Back Extension Hold x 1 min	Band Goodmorning x 12	Back Extension Hold x 1 min
Counter Balance Squat x 30sec	Monster Walk x 10e	Lateral Lunge Hold x 30 sec. Each Leg
Chin Up/Inverted Row Hold x 30 Sec	Push Up Hold x 30 sec.	Chin Up/Inverted Row x 30 sec.
Front Plank x 30s	Front Plank x 30s	Front Plank x 30s
	Relative Strength/ General Strength Circuit--3 Rounds	
Rotational Back Ext x 6e	Goblet Reverse Lunge x 6e	Russian Hamstrings x 10
Pause Goblet Squat x 10	Counter Balance Squat x 10--3 Sec. Pause @ Bottom	Goblet Split Squat x 10e
Chin Up/Inverted Row x 12	Push Up x 12	Chin Up/Inverted Row x 12
Russian Hamstrings x 10	OH Sit Up x 15--10lb. Plate	SL Hip Hinge w/ Pause x 10e

APPENDIX E

KNEE OUTCOME SURVEY SPORT ACTIVITY SCALE

Table 6

Knee Outcome Sport Activity Scale. Irrgang et al. (1998).

	Never Have	Have, but does not affect my sports activity	Affects sports activity slightly	Affects sports activity moderately	Affects sports activity severely	Prevent me from all sports activity
Pain	❍	❍	❍	❍	❍	❍
Grinding or Grating	❍	❍	❍	❍	❍	❍
Stiffness	❍	❍	❍	❍	❍	❍
Swelling	❍	❍	❍	❍	❍	❍
Slipping or partial giving away of knee	❍	❍	❍	❍	❍	❍
Buckling or full giving way of knee	❍	❍	❍	❍	❍	❍
Weakness	❍	❍	❍	❍	❍	❍
Functional Limitations with Sport Activities: How does your knee affect your ability to: (click one answer on each line)						
	Not difficult at all	Minimally difficult	Somewhat difficult	Fairly difficult	Very difficult	Unable to do
Run straight ahead	❍	❍	❍	❍	❍	❍
Jump and land on your involved leg	❍	❍	❍	❍	❍	❍
Stop and start quickly	❍	❍	❍	❍	❍	❍
Cut and pivot on your involved leg	❍	❍	❍	❍	❍	❍

APPENDIX F

AIM 1 DESCRIPTIVE STATISTICS

Table 7

Descriptive Statistics and T-Test Results for Knee:Ankle Ratio and Strength Exercises.

	Pretest		Postest			95% CI for Mean				Sig.
	Mean	SD	Mean	SD	n	Difference		t	df	(2-tailed)
Knee:Ankle Ratio	0.887	0.175	1.148	0.124	13	-0.387	-0.136	-4.543	12	0.001
Left Leg Isometric Lunge	22.615	3.330	31.385	3.927	13	-10.168	-7.370	-13.658	12	0.000
Right Leg Isometric Lunge	24.308	2.428	33.462	4.332	13	-10.913	-7.395	-11.338	12	0.000
Left Leg Isometric Glute Bridge	23.077	5.251	32.846	5.242	13	-11.568	-7.971	-11.834	12	0.000
Right Leg Isometric Glute Bridge	25.308	7.123	36.000	7.106	13	-12.641	-8.744	-11.956	12	0.000
Isometric Bodyweight Squat	33.000	6.468	44.077	6.184	13	-13.088	-9.066	-12.000	12	0.000

APPENDIX G

AIM 1 SPEARMAN CORRELATION

Table 8

Spearman Correlation of Difference in Average Knee:Ankle Ratio and Difference in Average of Strength.

		Difference in Average Knee:Ankle Ratio	Difference in Average Left Leg Isometric Lunge
Difference in Avearge Knee:Ankle Ratio	Correlation Coefficient	1.000	.976**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Left Leg Isometric Lunge	Correlation Coefficient	.976**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Right Leg Isometric Lunge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.906**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Right Leg Isometric Lunge	Correlation Coefficient	.906**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Left Leg ISO Lunge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.974**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Left Leg Isometric Glute Bridge	Correlation Coefficient	.974**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Right Leg Isometric Glute Bridge
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.943**
	Sig. (2-tailed)		0.000
	N	13.000	13.000
Difference in Average Right Leg Isometric Glute Bridge	Correlation Coefficient	.943**	1.000
	Sig. (2-tailed)	0.000	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

		Difference in Average Knee:Ankle Ratio	Difference in Average Isometric Body Weight Squat
Difference in Average Knee:Ankle Ratio	Correlation Coefficient	1.000	.732**
	Sig. (2-tailed)		0.004
	N	13.000	13.000
Difference in Average Isometric Body Weight Squat	Correlation Coefficient	.732**	1.000
	Sig. (2-tailed)	0.004	
	N	13.000	13.000

** Correlation is significant at the 0.01 level (2-tailed).

APPENDIX H

AIM 2 CONFIDENCE INTERVALS

Table 9

Confidence Intervals Comparing Injury Rates at Host School to Area Schools.

	Confidence Interval	
Girls Basketball	Lower	Upper
Host School School 2	-0.0456	0.0537
Host School School 3	-0.0313	0.0757
Host School School 4	-0.0368	0.0705

The injury rate at School 2 could be as much as 5.4% higher or as much as 4.6% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

The injury rate at School 3 could be as much as 7.6% higher or as much as 3.13% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

The injury rate at School 4 could be as much as 7.1% higher or as much as 3.7% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

	Confidence Interval	
Girls Volleyball	Lower	Upper
Host School School 2	-0.0234	0.0396
Host School School 3	-0.0172	0.0696
Host School School 4	-0.0117	0.0765

The injury rate at School 2 could be as much as 4.0% higher or as much as 2.34% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

The injury rate at School 3 could be as much as 7.0% higher or as much as 1.72% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

The injury rate at School 2 could be as much as 7.7% higher or as much as 1.2%% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

	Confidence Interval	
Girls Soccer	Lower	Upper
Host School School 2	-0.0158	0.0632
Host School School 3	-0.0249	0.0403
Host School School 4	-0.0219	0.0515

The injury rate at School 2 could be as much as 6.3% higher or as much as 1.6% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

The injury rate at School 3 could be as much as 4.03% higher or as much as 2.5% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

The injury rate at School 4 could be as much as 5.2% higher or as much as 2.2% lower (or anywhere in between). Since the interval allows that either proportion could be higher, it cannot be concluded statistically that the proportion at the Host school would be higher.

APPENDIX I

AIM 2 INJURY RATIOS

Table 10

Injury Ratios.

	Host School	School 2	School 3	School 4
Girls BB	0.018	0.020	0.037	0.031
Girls VB	0.007	0.000	0.027	0.000
Girls Soccer	0.011	0.030	0.018	0.022

APPENDIX J

SPEARMAN CORRELATION SCATTERPLOTS

Figure 1

Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Left Leg ISO Lunge.

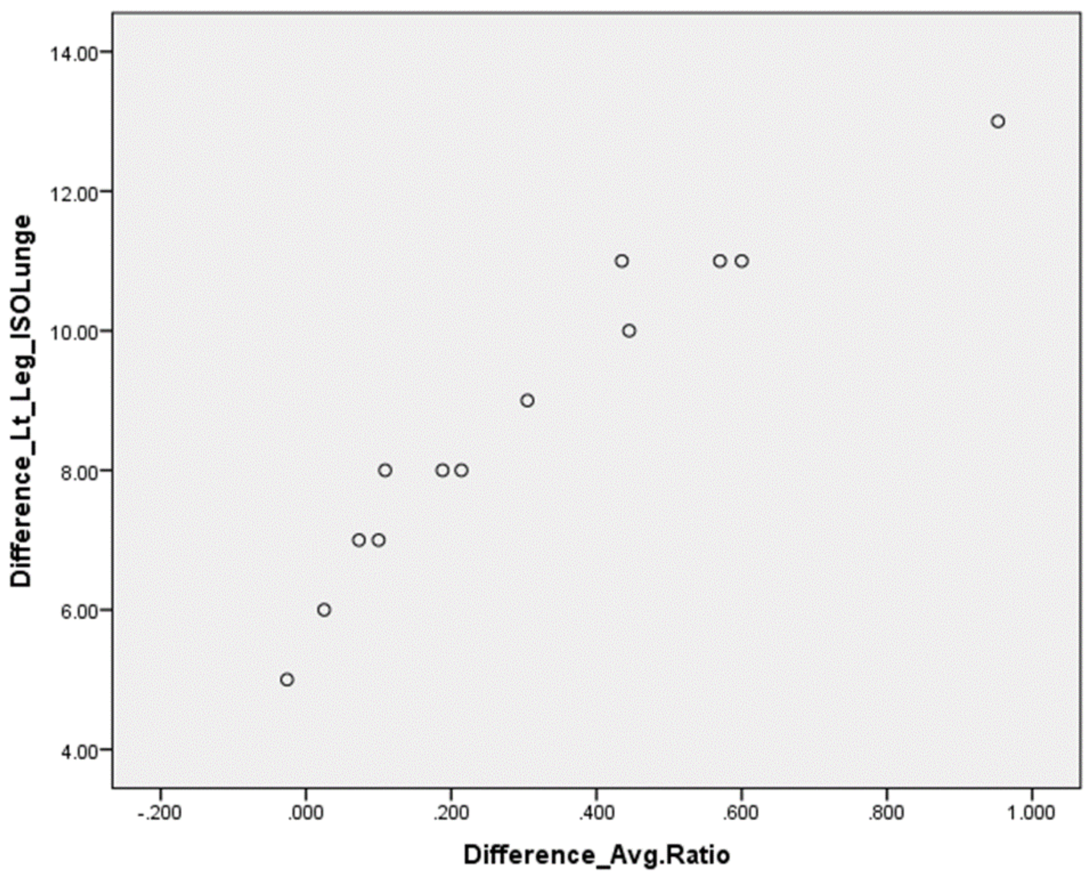

Figure 2

Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Right Leg ISO Lunge.

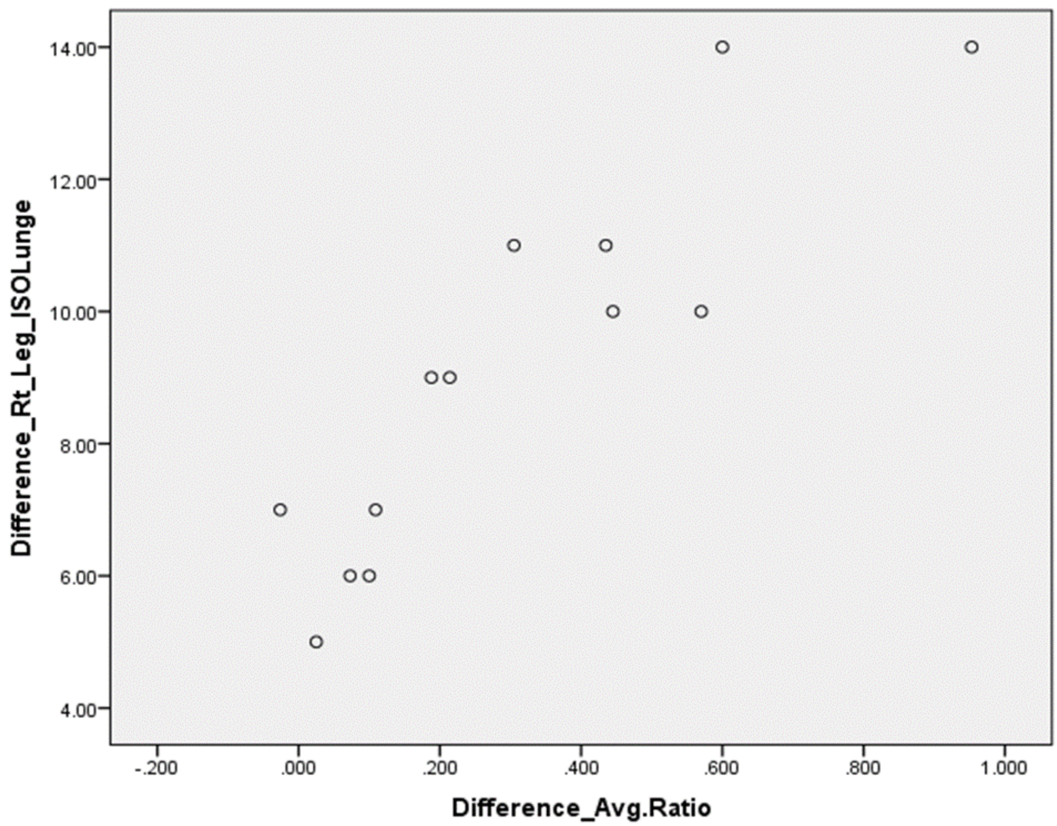

Figure 3

Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Left Leg ISO Glute Bridge.

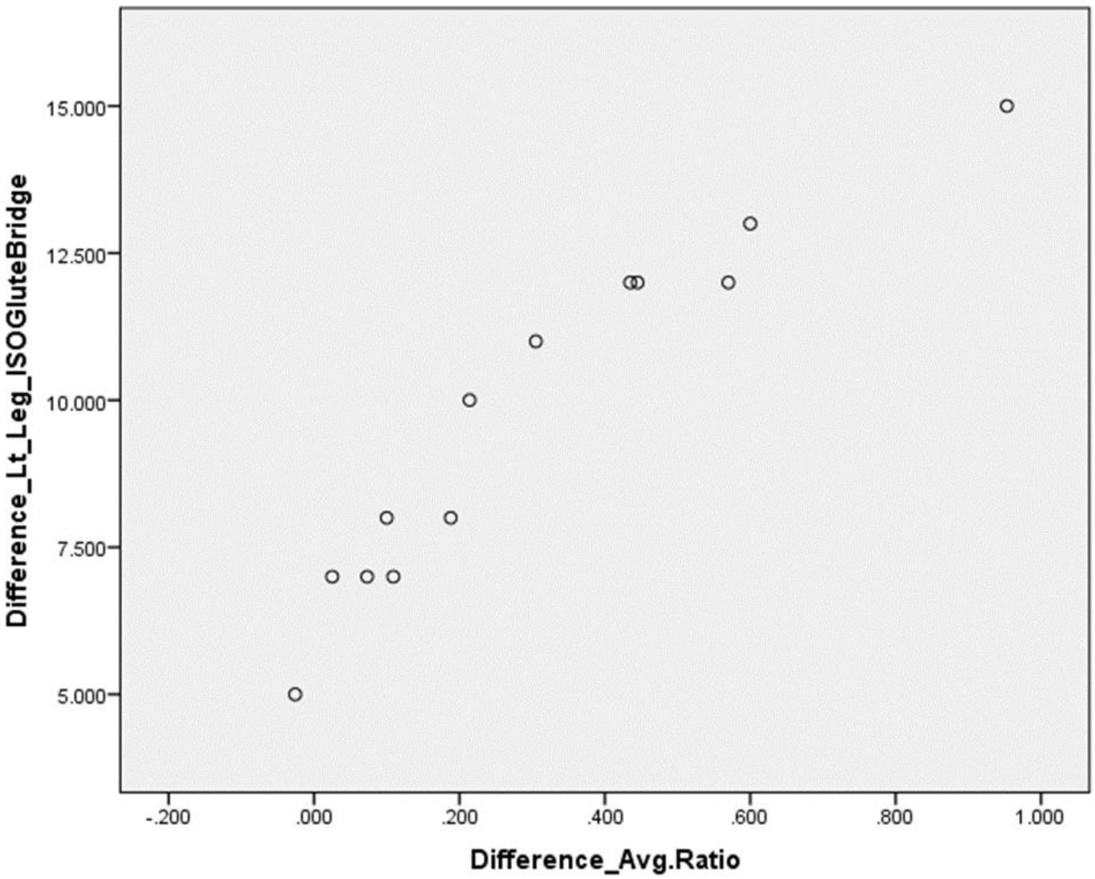

Figure 4

Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for Right Leg ISO Glute Bridge.

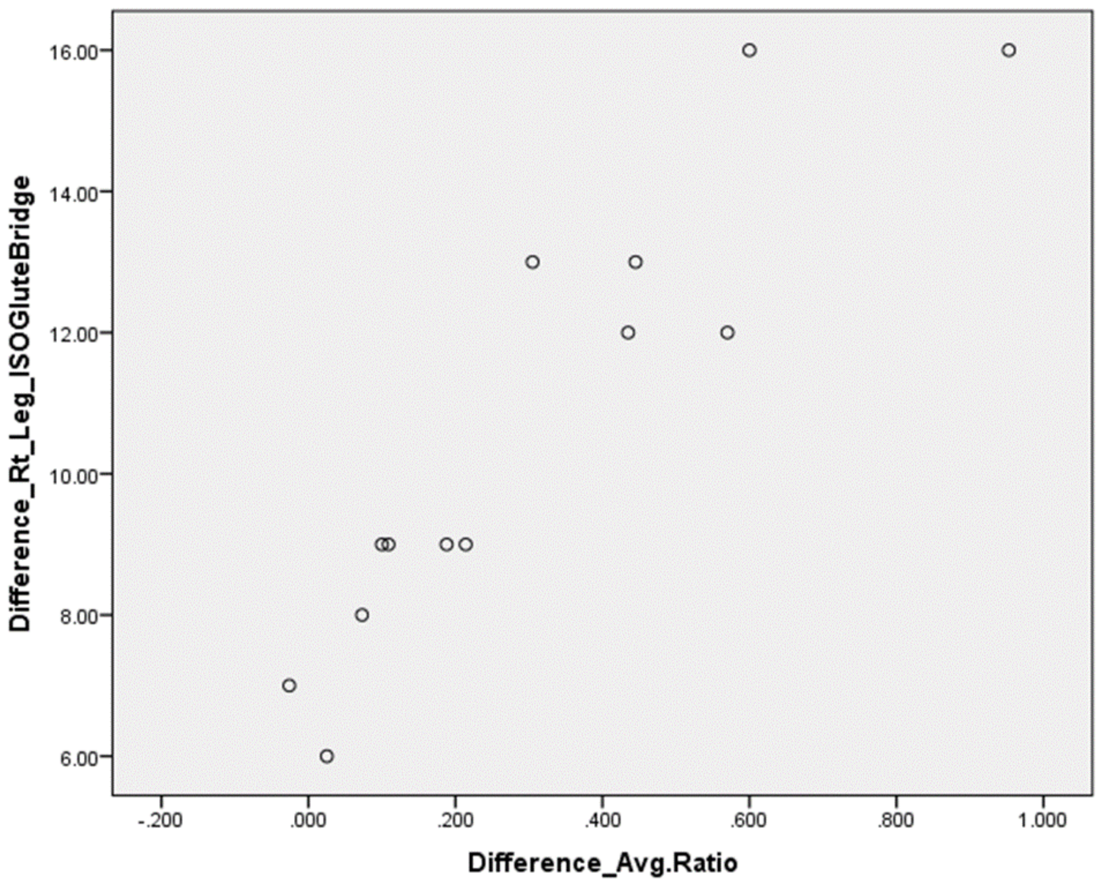

Figure 5

Difference Average Knee:Ankle Ratio to Difference Pre-Post Strength for ISO Body Weight Squat.